



## **Future visions for electric vehicle deployment in Denmark: stakeholder based scenario development.**

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# Future visions for electric vehicle deployment in Denmark: stakeholder based scenario development

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28 March, 2017



# Context

Fossil-free Denmark by 2050

Electrification of vehicle fleet necessary; also biggest challenge



- *What are the implications for the electricity grid and other energy and transport infrastructure?*
- *What are the implications for modal choice and travel time budgets?*
- *What are the policy relevant scenarios for the future?*

- TIMES-DK linear optimization model of Danish energy system
- Transport in TIMES-DK: Optimization of tech and fuel to meet expanded TIMES-DK demand modes are exogenous (i.e. shares of buses fixed)
- Modal choice (travel time budget /investment, speed, trip purpose)
- Infrastructure capacity and requirements

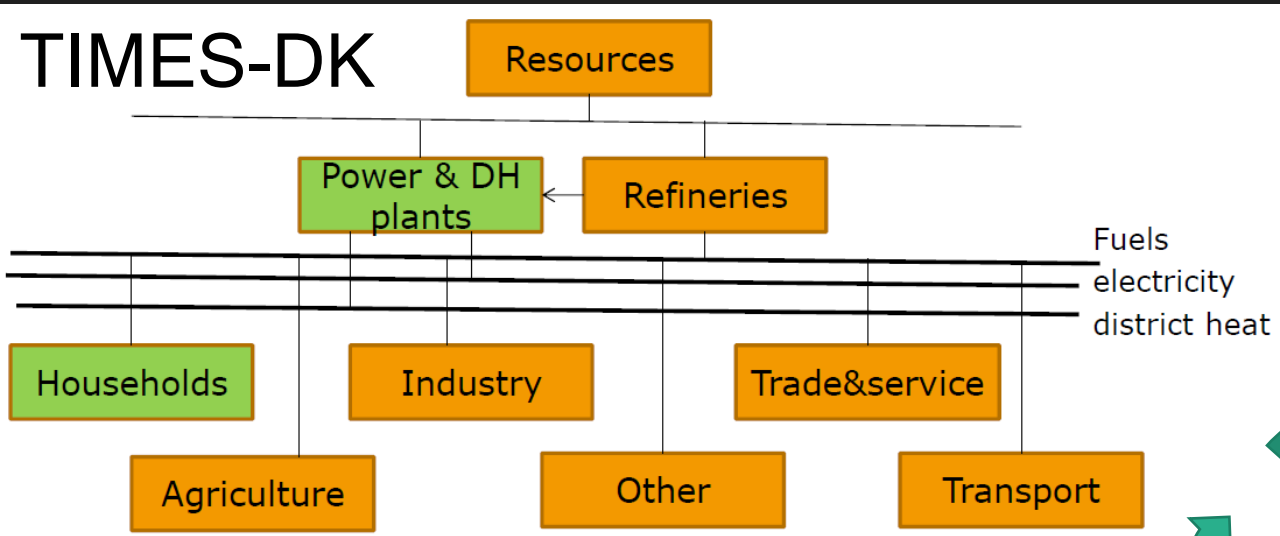


# Factors to consider: unanswered modeling questions

- Travel Time Investment (TTI): Investing in bus infrastructure (lanes, number of busses) reduces the waiting time and travel time for busses, which has societal value.
- Demand segmentations: Discomfort costs are different depending by the demand segments. The overall land travel demand should be split to calculate different costs for different segments.
- Value of Time (VoT): Is VoT mode specific? VoT reflects the income of people taking the mode, but also depends also on the length of the trip.
- Trip vs tours: Distinguish between trips and tours. A tour (urban to rural travel) is constrained to the same transport means as a trip.



# Soft-link between TIMES & LTM (method proposed in COMETS)



**TIMES-DK → LTM:** Optimal fuel and technology mix, travel cost by mode

**LTM → TIMES-DK:** Modal choice, short and long distance travel demand

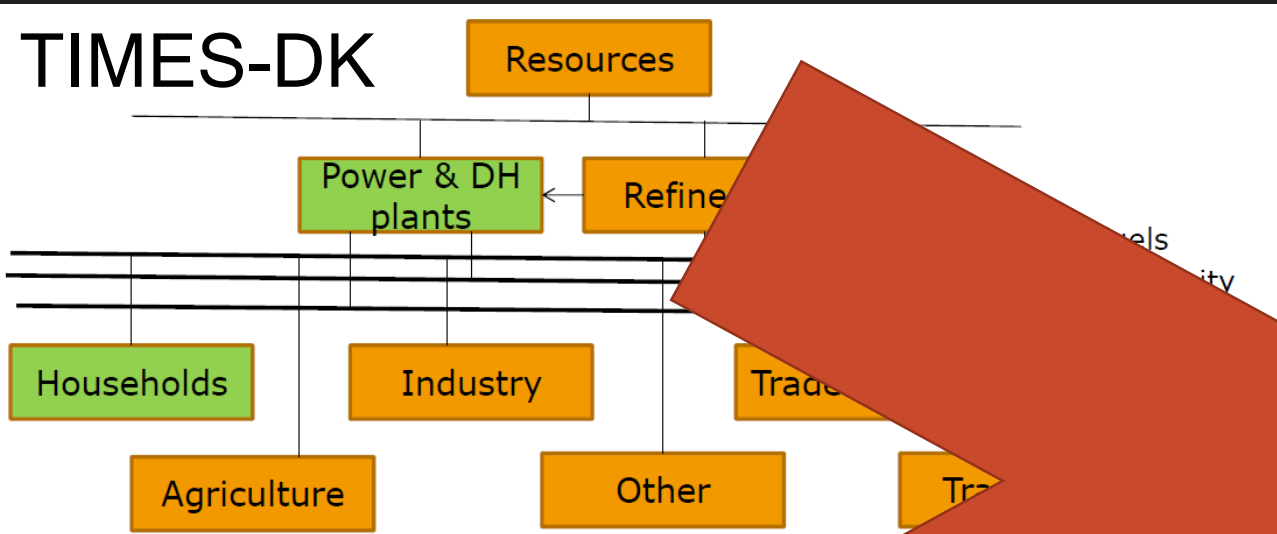
*But...*

- LTM does not allow setting CO<sub>2</sub> caps: emission reduction scenarios in TIMES-DK would be inconsistent with LTM; LTM not sensitive to fuel price
- LTM is highly geographically disaggregated geographically (trips for each household). When aggregating to TIMES-DK, LTM output loses meaning and a lot of biases appear, especially in iterative analysis

**LTM: Landstrafikmodellen**



# Sort-link between TIMES & LTM (method proposed in COMETS)



**TIMES-DK → LTM:** Optimal fuel and technology mix, travel mode

**TIMES-DK:** Modal split and long distance travel demand

*But...*

- LTM does not allow setting reduction scenarios in TIMES; LTM is inconsistent with LTM; LTM is sensitive to fuel price
- LTM is highly geographically disaggregated geographically (trips for each household). When aggregating to TIMES-DK, LTM output loses meaning and a lot of biases appear, especially in iterative analysis

fikmodellen



# A story-and-simulation (SAS) approach

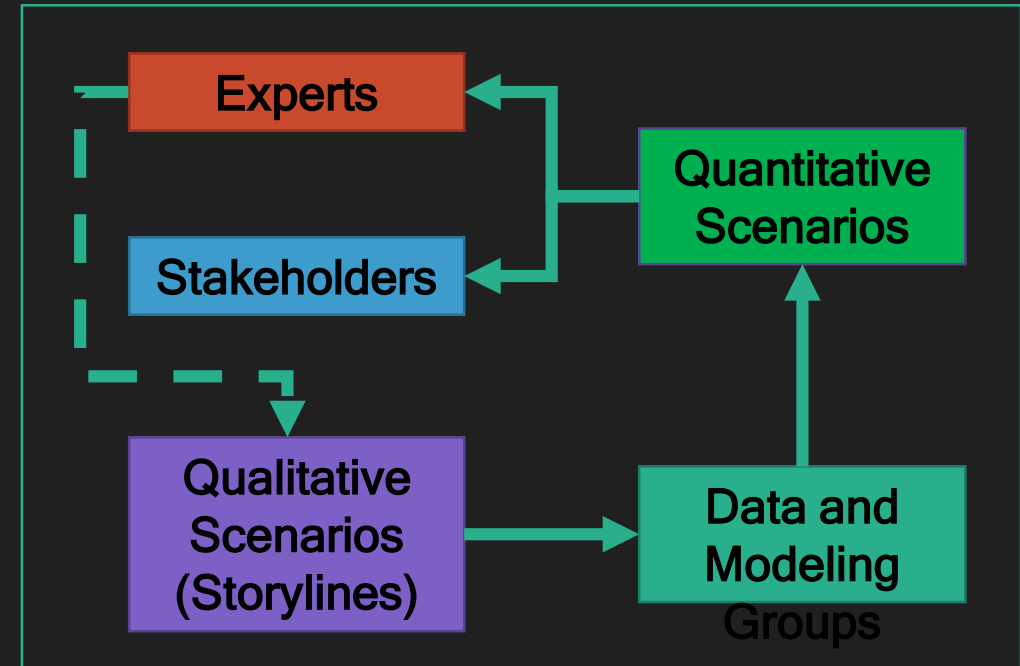
## Stakeholder panel

- Discuss driving forces and uncertainties
- Develop qualitative storylines

## Experts (data & modeling groups)

- translate the qualitative information into quantitative model input
- underpin qualitative analysis by quantitative modeling as feedback

**Iteration (Stakeholders and experts)** refine storylines and quantification until a set of compelling, plausible and relevant stories and simulations about the future is reached



Based on European Environment Agency (2007)

*Land-Use Scenarios for Europe: Qualitative and Quantitative Analysis on a European Scale.*

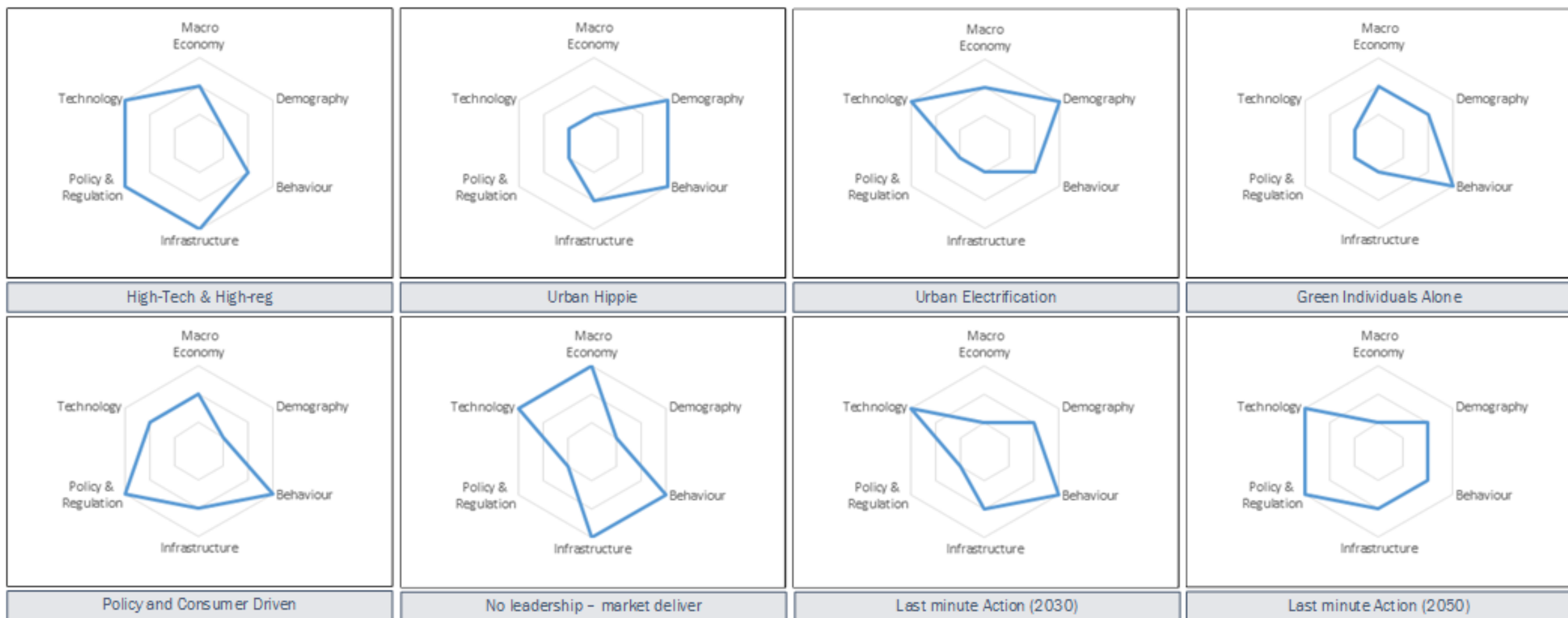




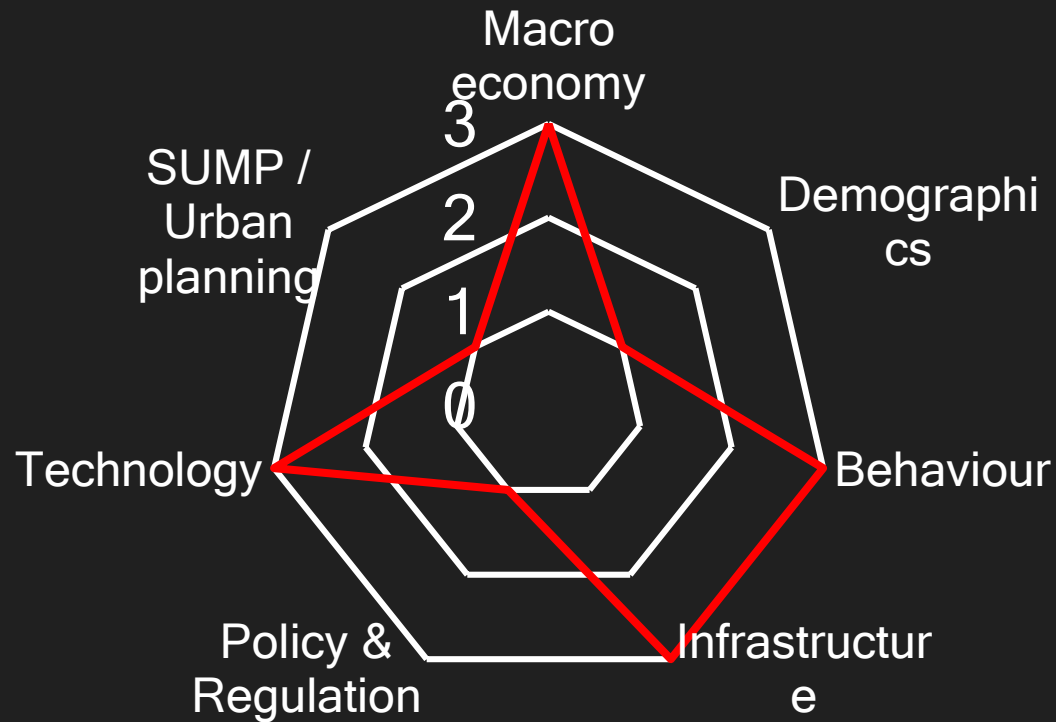
# Stakeholder / Expert workshop, Sept. 2016

- Brainstorm in groups of 3 on driving forces for transport sector, and present PostIt notes
- Cluster the driving forces (around 20)
- Place green dots on the clusters with highest **impact** (8 votes each)
- Place red dots on the clusters with highest **uncertainty** (8 votes each)
- Agree on the most important 5 clusters (key drivers)
- Create scenarios based on key drivers (ca 10 minutes)
  - Groups develop scenario based on (low, medium, high) values of the five key drivers
  - Write a narrative (story) for each scenario in the form of bullet points

# Scenario storylines from expert workshop

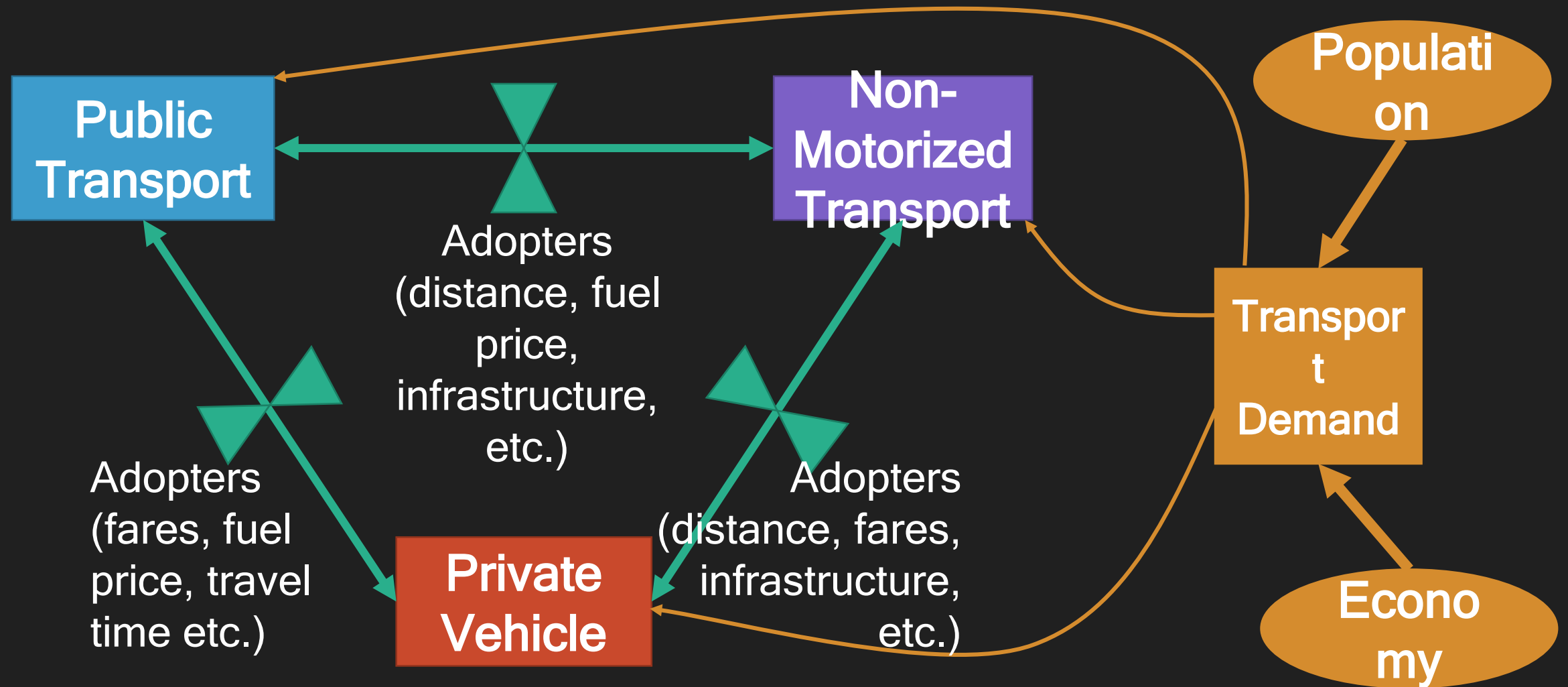


# Example Narrative from Stakeholders: “No leadership - market delivered”



- Minimal or no national & international political leadership
- No Sustainable Urban Management Plan (SUMP)
- High degree of technological development & innovation in power production, charging and batteries
- Private development of infrastructure
- High economic and environmental consciousness behavior
- High oil prices

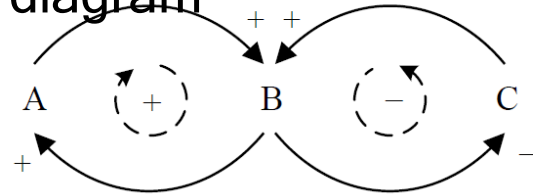
# Modal Choice and Human Behavior



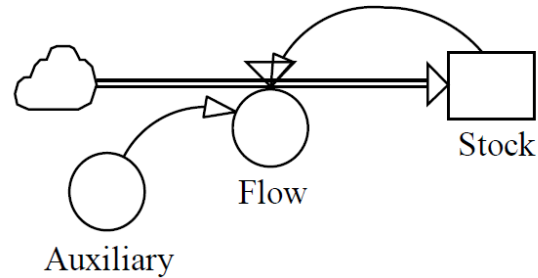
# Modal Choice and Human Behavior: System Dynamics

Goal: to understand motivations behind modal choice, and create a system

Casual loop diagram



Stock-flow



Potential validation through stakeholder interviews

Compare with an Agent Based Model

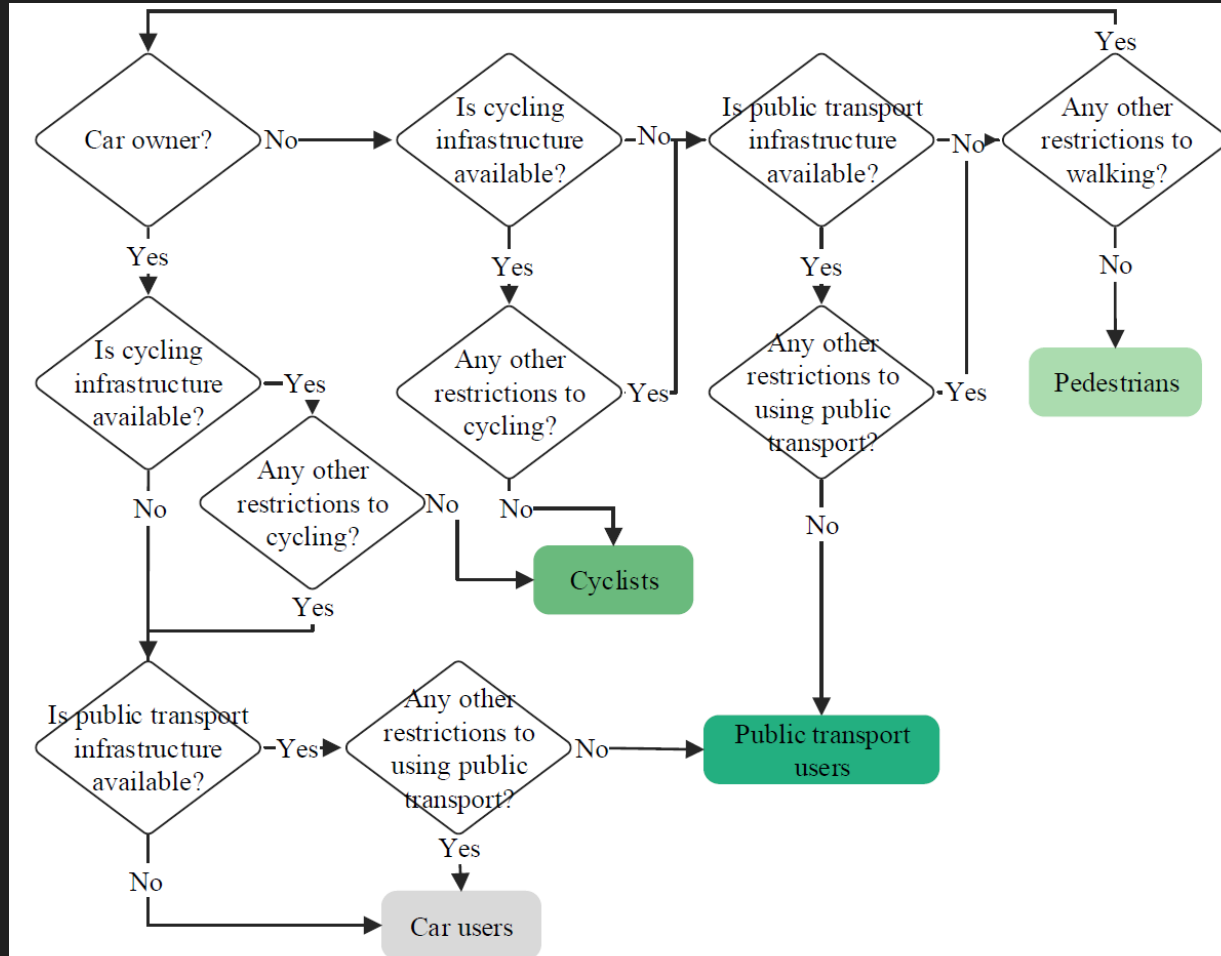















Figure 4.7. An algorithm of passenger transport trip choice model incorporated in the system dynamics model



# Car Sharing and Entrepreneurship Models

Ownership

Flexibility

	Flexibility		
	Round Trip	Station	Floating
Firm-to-Customer	<p>Hertz Lyngby Delebil Tadaa!</p>    	<p>NordSjaelland</p> 	<p>DriveNow Green Mobility</p>  
Cooperative	<p>Letsgo Albertslund delebil</p>  		
Peer to Peer	<p>GoMore Snappcar</p>  		
Other	<p>Arval</p> 		<p>Spiri</p> 

Elisa

# Car Sharing and Entrepreneurship Models

- Business Model Canvas Comparison:
- Value Proposition (VP)
- Channels (CH)
- Revenue Streams (RS)
- Key Activities (KA)
- Customer Segments (CS)
- Future Potential: how are these related to ownership and flexibility?
- How does this affect modal choice scenarios?










**The Business Model Canvas**

Designed for: \_\_\_\_\_

Designed by: \_\_\_\_\_

On: \_\_\_\_\_

Iteration: \_\_\_\_\_

<b>Key Partners</b>  Who are our Key Partners? Who are our key suppliers? Which Key Resources are we acquiring from partners? Which Key Activities do partners perform? <b>KEY RESOURCES</b> Infrastructure and equipment Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities	<b>Key Activities</b>  What Key Activities do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue streams? <b>KEY RESOURCES</b> Infrastructure Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities	<b>Value Propositions</b>  What value do we deliver to the customer? Which one of our customer's problems are we helping to solve? What bundles of products and services are we offering to each Customer Segment? Which customer needs are we satisfying? <b>KEY RESOURCES</b> Infrastructure Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities	<b>Customer Relationships</b>  What type of relationship does each of our Customer Segments expect us to establish and maintain with them? Which ones have we established? How are they integrated with the rest of our business model? How costly are they? <b>KEY RESOURCES</b> Infrastructure Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities	<b>Customer Segments</b>  For whom are we creating value? Who are our most important customers? How do they behave? What are their needs? What are their expectations? What are their pain points?
<b>Key Resources</b>  What Key Resources do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue Streams? <b>KEY RESOURCES</b> Infrastructure Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities	<b>Channels</b>  Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-efficient? How are we integrating them with customer routines? <b>KEY RESOURCES</b> Infrastructure Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities			
<b>Cost Structure</b>  What are the most important costs inherent in our business model? Which Key Resources are most expensive? Which Key Activities are most expensive? <b>KEY RESOURCES</b> Infrastructure Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities		<b>Revenue Streams</b>  For what value are our customers really willing to pay? For what do they currently pay? How are they currently paying? How would they prefer to pay? How much does each Revenue Stream contribute to overall revenues? <b>KEY RESOURCES</b> Infrastructure Human resources Financial resources Channels and distribution Partnership network Acquisition of particular resources and activities		

[www.businessmodelgeneration.com](http://www.businessmodelgeneration.com)

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# Game Changers: Autonomous Vehicles

SAE Level	SAE name	SAE narrative definition	Execution of steering and acceleration/deceleration	Monitoring of driving environment	Fall-back performance of dynamic driving task	System capability (driving mode)
Human driver monitors the driving environment			Human driver	Human driver	Human driver	n.a.
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems				
1	Driver Assisted	the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> performs all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment			System	System	Human driver	Some driving modes
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a request to intervene				
4	High Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a request to intervene	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes

Forecasts:

2018-2020: Nutor

2018: Tesla

2018: NVIDIA (Level 4)

2019: Delphi & Mob

2019: VW

2019: Baidu

2020: GM

2020: Nissan (Level 4)

2020: Toyota (Level 4)

2020: Audi (Level 4)

2021: Ford (Level 5)

2021: BMW

2023: Tesla (Level 5)

2040: IEEE 75% wil

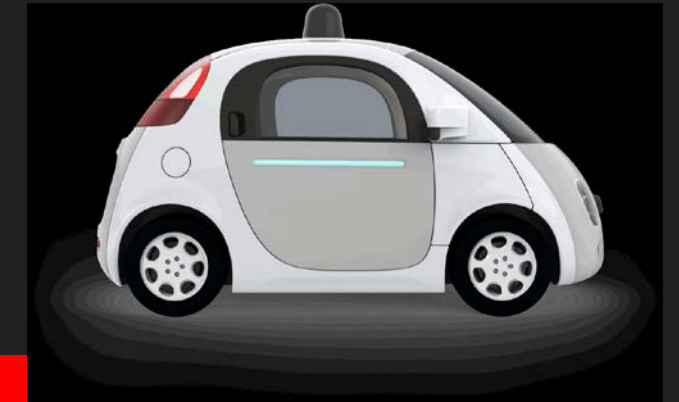
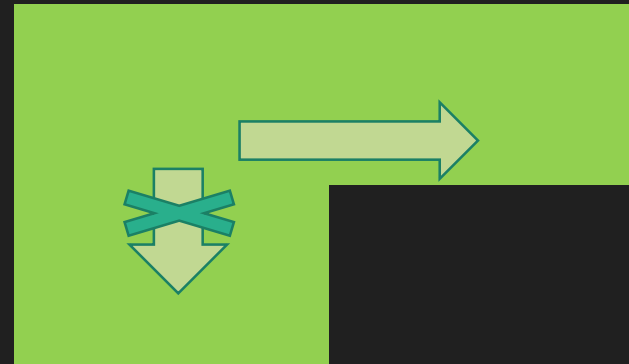
# Disruptive Technological Development: Autonomous Cars

Motorways w. hard shoulder      Two-lane expressway      Mixed-use highway      Urban streets      Private roads and streets

Level 3

Level 4

Level 5



- The future scenarios: Privately owned vehicles vs. Mobility as a service
- What does it mean for public transport?
- What does it mean for non motorized transport?

Per Homann

A Level 5 car has no steering wheel or pedals, so needs access to all streets



# Conclusions

- Major changes in the future!
  - Transport becomes electrified
  - Transport becomes a service
- Tech depends on social factors
- Difficult to model!
- Participatory scenarios

